# Rotordynamics on the PC: Transient Analysis With ARDS

Personal computers can now do many jobs that formerly required a large mainframe computer. An example is NASA Lewis Research Center's program Analysis of RotorDynamic Systems (ARDS), which uses the component mode synthesis method to analyze the dynamic motion of up to five rotating shafts. As originally written in the early 1980's, this program was considered large for the mainframe computers of the time.

ARDS, which was written in Fortran 77, has been successfully ported to a 486 personal computer. Plots appear on the computer monitor via calls programmed for the original CALCOMP plotter; plots can also be output on a standard laser printer. The executable code, which uses the full array sizes of the mainframe version, easily fits on a high-density floppy disk. The program runs under DOS with an extended memory manager. In addition to transient analysis of blade loss, step turns, and base acceleration, with simulation of squeeze-film dampers and rubs, ARDS calculates natural frequencies and unbalance response.
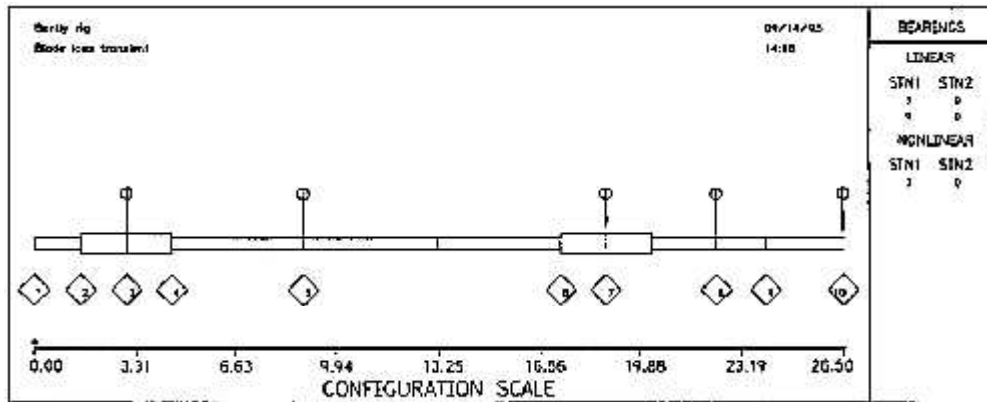

ARDS drawing of example rotor.

ARDS-PC was used to analyze a magnetic-bearing-supported rotor (a small rotordynamics demonstrator rotor) as it experiences a sudden increase in imbalance or drops onto backup bearings. ARDS draws an outline of the rotor configuration, which appears in the figure above for the example rotor. This rotor was modeled with 9 elements, resulting in 10 rotor stations. Concentrated masses were attached to the shaft at 5 of the stations. An electromagnetic bearing was at station 3, and a bronze bushing supported the shaft at station 8. Magnetic bearings are customarily used with "backup" bearings that can support the rotor if the magnetic bearing fails. For this example, a backup bearing in the form of a loose bushing was modeled in addition to the magnetic bearing at station 3. No contact occurred in the backup bearing during normal (magnetically suspended) operation; therefore, the backup bearing was nonlinear in that the stiffness was zero until the radial clearance was taken up. It was then assumed to have a constant stiffness in the radial direction; the tangential force was calculated as the radial force times a friction coefficient. This bearing model was built into ARDS. Each computer

run used 100 time steps per revolution. On the 50-MHz 486 computer used, 4000 time steps took slightly less than 2 min calculation time.

A blade loss in a turbine engine introduces a sudden imbalance that can be many times the normal operating imbalance. Under this condition, the magnetic bearing supporting the rotor can become overloaded to the point that the backup bearing comes into operation. As the bearing makes contact, the situation is similar to that of a turbine wheel contacting its outer shroud. The following figure shows 10 revolutions of a blade loss transient with an active linear magnetic bearing and a friction coefficient of 0.4 assumed for the backup bearing. This figure is an orbital plot of the rotor at station 3, the magnetic bearing location. The imbalance is applied to the rotor at station 5. The plot shows that the rotor flies out, hits the backup bearing, bounces off, and repeats this behavior for the entire time period plotted.

DISPLACEMENT CROSS PLOT

STATION NUMBER   3   TRAN, Z-DIR, VS   TRAN, Y-DIR
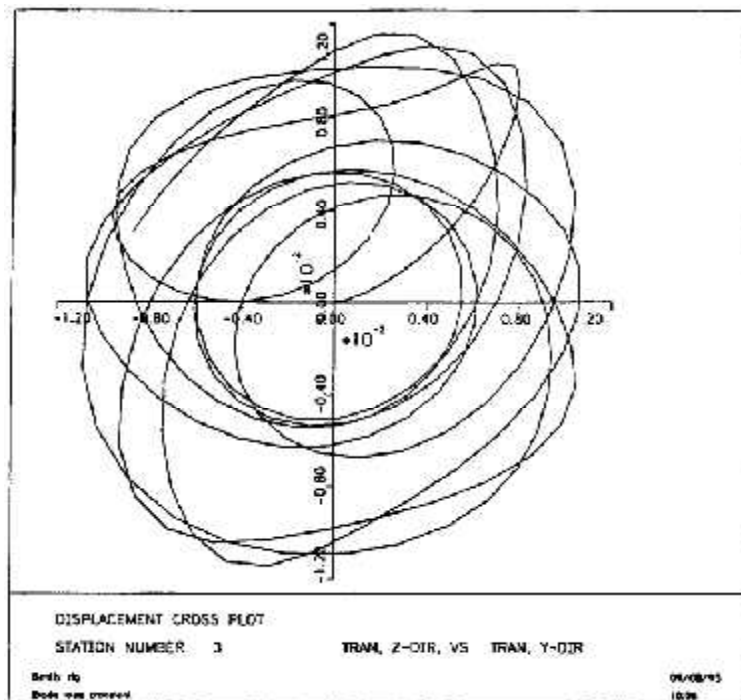
Orbital motion of magnetic and backup bearing for sudden imbalance.

The final figure plots the dynamic behavior of the rotor when the magnetic support fails and the rotor drops onto the backup bearing. The rotor walks up the side of the bearing, although the more sensitive scale for the horizontal axis in this figure exaggerates this motion. The vibratory motion eventually dies down. Excitation forces can be combined: for example, a turn combined with blade loss and base acceleration.
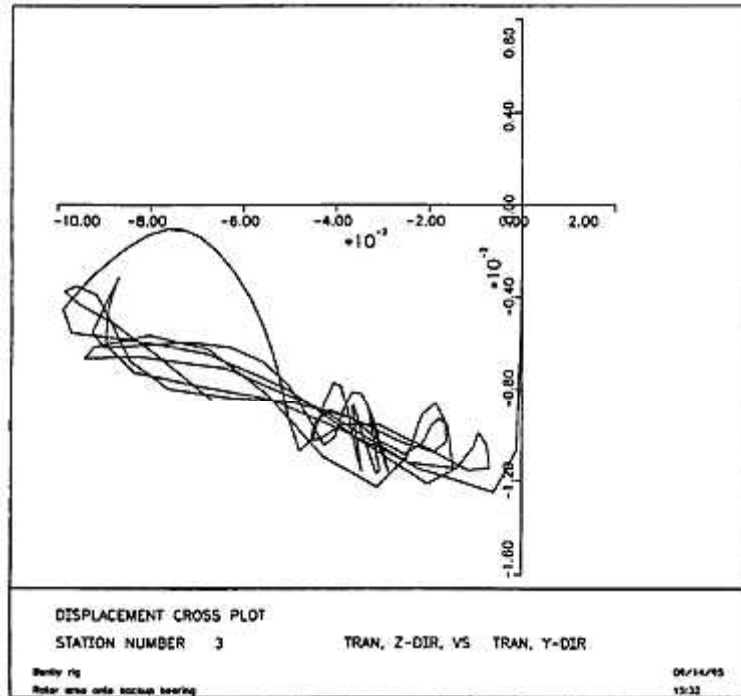
Rotor drop onto backup bearing.

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